MSl12 Version 3.0 User's Guide

Bryan A. Franz

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I. Introduction

MSl12 is the multi-sensor level-1 to level-2 processing code developed by the National Aeronautics and Space Administration's (NASA) Sensor Intercomparison and Merger for Bio-optical and Interdisciplinary Oceanic Studies (SIMBIOS) project. The software tool is capable of performing atmospheric correction of top-of-atmosphere (TOA) radiances from several ocean remote sensing, spaceborne spectrometers, including SeaWiFS, OCTS, MOS, OSMI, and POLDER, and deriving atmospheric and bio-optical properties using identical algorithms for all sensors. Data input format and sensor identification are automatically determined by the program, which presently recognizes SeaWiFS Level-1A and Level-1B, OCTS Level-1B (NASDA and SIMBIOS formats), MOS Level-1B, OSMI Level-1A, and POLDER Level-1B. Sensor-dependent details such as band-pass-weighted quantities are included in a sensor-specific external data file, and pre-computed sensor-specific look-up tables are provided for Rayleigh scattering and Rayleigh-aerosol transmittance. Aerosol model tables make use of SeaWiFS-specific coefficients, with some adjustment of the model epsilons to correct for deviations from SeaWiFS center wavelengths. The use of pre-computed SeaWiFS aerosol tables limits the ability of MSl12 to perform atmospheric correction for sensors that significantly deviate from SeaWiFS wavelengths, or sensors that contain more than six wavelengths in the 400-700 nm range (e.g., MOS).

By convention, the italicized word *sensor* is used herein to mean octs, mos, osmi, polder, or seawifs.

II. Run-time Environment

To locate the input files associated with each sensor, MSl12 uses a Unix environment variable, MSL12_DATA, to locate the top of the directory tree. Sensor data files are then located relative to that root directory. The directory tree must be organized as follows:

```
$MSL12_DATA
      seawifs
            cal
            aerosol
            rayleigh
            transmittance
      mos
            cal
            rayleigh
            transmittance

      octs
            rayleigh
            transmittance
```

```
polder
      rayleigh
      transmittance
osmi
      cal
      rayleigh
      transmittance
common
      S19461993_COADS_GEOS1.MET_noon
      S19891991_TOMS.OZONE
      f0_table.dat
      sst_climatology.hdf
      alpha510_climatology.hdf
      taua865_climatology.hdf
      landmask.dat
      watermask.dat
      ice_mask.hdf
      digital_elevation_map.hdf
```

The top-level directory associated with each sensor (e.g., $MSl12_DATA/*sensor*) contains a sensor-specific data file (e.g., *sensor*_table.dat) to provide wavelength information and band-pass-weighted quantities. The directory may also contain a *sensor*_def_l2prod.dat file to specify a default set of Level-2 products, and a default filter specification file named *sensor*_filter.dat. Examples for each supported sensor are listed in Appendix I. Within each sensor directory, there are sub-directories to hold Rayleigh tables and Rayleigh-aerosol diffuse transmittance tables. The SeaWiFS sub-directory also contains aerosol model tables. Some sensor directories may contain a calibration sub-directory called cal.

III. Calling Sequence

MSl12 is designed to be as general as possible, with many parameters available to control the processing, and a user-specifiable output content. Input parameters are passed to the program through a series of keyword-value pairs, which can be specified directly on the command-line or inserted as single lines in an input parameter file. It is also possible to use both methods simultaneously, if for instance the user wanted to use a standard parameter file but vary the input and output files on the command-line. In it's most basic form, with all parameters defaulted, the calling sequence is simply:

% MSl12 ifile=input_file_name ofile1=output_file_name

or

% MSl12 par=parameter_file_name

where the file specified by parameter_file_name contains the two lines:

```
ifile=input_file_name
```

```
ofile1=output_file_name
```

This will produce an HDF output file with default content, typical of SeaWiFS standard level-2 products. In general, the user can specify which science dataset (SDS) to put in the output file; and, the user can specify multiple output files with different content in each. As a simple example, the following parameter file would process a SeaWiFS LAC file and generate two output files, the first with nLw for bands 1-6, and the second with chlorophyll-a (using the OC2 algorithm).

```
ifile=S1999180212700.L1A_LAC
ofile1=S1999180212700.L2_LAC
l2prod1=Lw_412 Lw_443 Lw_490 Lw_510 Lw_555 Lw_670
ofile2=S1999180212700.CHL_LAC
l2prod2=chl_oc2
```

It is also possible to request the default products plus one or more additional products by using the product keyword "default" in the product list. For example:

```
l2prod1=default angstrom_520 aer_model_min aer_model_max aer_ratio
```

The list of available output products is somewhat sensor specific, since the SDS names are specified by wavelength. The complete list of specifiable output SDS names is listed below. The default output products for each sensor are defined in the *sensor*_def_l2prod.dat files located in $MSL12_DATA/*sensor*.

Product (SDS) Name	**Definition**
chlor_a	Default chlorophyll-a algorithm (currently chl_oc4 for all sensors).
chl_oc2	Chlorophyll-a, OC2 algorithm
logchl_oc2	Log10 of chlorophyll-a, OC2 algorithm
pig_oc2	Pigment concentration derived from chl_oc2
chl_oc4	Chlorophyll-a, OC4 algorithm
logchl_oc4	Log10 of chlorophyll-a, OC4 algorithm
pig_oc4	Pigment concentration derived from chl_oc4
chl_octsc	Chlorophyll-a, OCTS-C algorithm
logchl_octsc	Log10 of chlorophyll-a, OCTS-C algorithm
pig_octsc	Pigment concentration derived from chl_octsc
chl_ndpi	Chlorophyll-a derived from pig_ndpi
logchl_ndpi	Log10 of chlorophyll-a derived from pig_ndpi
pig_ndpi	Normalized difference pigment index
chl_nn	Chlorophyll-a derived from pig_nn
logchl_nn	Log10 of chlorophyll-a derived from pig_nn
pig_nn	Neural network pigment algorithm (SeaWiFS only)
chl_gsm01	Chlorophyll-a derived from fit to Garver-Siegel-Maritorena 2001 model
bbp_gsm01	Particulate backscatter coefficient, Garver-Siegel-Maritorena 2001 model
acdm_gsm01	Absorption from colored, disolved matter, Garver-Siegel-Maritorena 2001 model
logchl_gsm01	Log10 of chl_gsm01
K_490	Diffuse attenuation coefficient at 490 nm
evi	Enhanced vegetation index
ndvi	Normalized difference vegetation index

Product (SDS) Name	Definition
depth	Water depth index (R. Stumpf)
aerindex	Aerosol index (C. Hsu)
smoke	Smoke index (E. Vermote)
par	Photosynthetically active radiation (R. Frouin)
calcite	Calcite concentration (Gordon and Balsh)
aer_model_min	Minimum bounding aerosol model #
aer_model_max	Maximum bounding aerosol model #
aer_model_ratio	Model ,mixing ratio
aer_num_iter	Number of aerosol iterations, NIR correction
cloud_albedo	Reflectance used for cloud/ice thresholding
glint_coef	Glint radiance normalized by solar irradiance
epsilon	Retrieved epsilon used for model selection (float)
eps_78	Retrieved epsilon used for model selection (byte)
solz	Solar zenith angle
sola	Solar azimuth angle
senz	Sensor zenith angle
sena	Sensor azimuth angle
fsol	Earth-Sun distance correction factor (per scan)
t_f	Fresnel transmittance through sea surface
l2_flags	Level-2 processing flags (see Table 2.)
sst	Sea surface temperature (derived from climatology)
height	Terrain height (from digital_elevation_map.hdf)
ozone	Ozone concentration (from input ancillary data)
windangle	Wind direction (deg), from N = 0, from E = 90
windspeed	Magnitude of wind (m/s)
zwind	Zonal wind speed (m/s)
mwind	Meridional wind speed (m/s)
water_vapor	Precipital water concentration
pressure	Barometric pressure
humidity	Relative humidity
In the SDS names that follow, nnn should be replaced with the wavelength of the 3-digit center wavelength. The wavelengths associated with each sensor are listed in the respective "sensor"_table.dat files (Appendix I).	
nLw_nnn	Normalized water-leaving radiance
Lw_nnn	Water-leaving radiance
Lr_nnn	Rayleigh radiance
La_nnn	Aerosol radiance (Not valid over land).
TLg_nnn	TOA glint radiance
tLf_nnn	Foam (white-cap) radiance
Lt_nnn	Calibrated TOA radiance
t_sol_nnn	Rayleigh-aerosol transmittance, sun to ground
t_sen_nnn	Rayleigh-aerosol transmittance, ground to sensor
t_oz_sol_nnn	Ozone transmittance, sun to ground
t_oz_sen_nnn	Ozone transmittance, ground to sensor
t_h2o_nnn	Total water vapor transmittance; just a rough estimate used for land surface reflectance estimates. La is already adjusted to remove water-vapor effects over oceans.
t_o2_nnn	Total oxygen transmittance; just the effect on aerosol path radiance, La. Lr is already reduced by O2 absorption. Not valid over land.

Product (SDS) Name	**Definition**
taua_nnn	Aerosol optical depth
tau_nnn	Alternate name for taua_nnn
angstrom_nnn	Aerosol angstrom coefficient, α(nnn,865)
Es_nnn	Extra-terestrial surface irradiance
rhos_nnn	Surface reflectance
rhot_nnn	Top-of-atmosphere reflectance
Rrs_nnn	Remote sensing reflectance (nLw/F0)
tauc_nnn	Cloud optical depth (band 8, SeaWiFS GAC only)

Table 1: *MSl12 product list.*

Flag	Flag Name	Description
1	ATMFAIL	atmospheric correction failure
2	LAND	land in pixel
3	BADANC	bad ancillary data
4	HIGLINT	high sun glint
5	HILT	high radiance
6	HISATZEN	high satellite zenith angle
7	COASTZ	shallow water
8	NEGLW	negative Lw (400-600 nm)
9	STRAYLIGHT	stray light
10	CLDICE	cloud and/or ice
11	COCCOLITH	coccolithophores may be present
12	TURBIDW	turbid water
13	HISOLZEN	high solar zenith angle
14	HITAU	high aerosol optical thickness
15	LOWLW	low Lw 555 (cloud shadow)
16	CHLFAIL	chlorophyll algorithm failure
17	NAVWARN	reduced navigation quality (tilt changing)
18	ABSAER	absorbing aerosols detected
19	TRICHO	trichodesmium may be present
20	MAXAERITER	NIR aerosol iteration did not converge
21	MODGLINT	moderate sun glint contamination
22	CHLWARN	chlorophyll exceeds nominal range (0.0-100)
23	ATMWARN	atmospheric correction is suspect
24	DARKPIXEL	Rayleigh path radiance exceeds observered
25	SEAICE	Sea ice (from climatology)
26	NAVFAIL	Navigation error
32	OCEAN	Not cloud and not land

Table 2: *Level-2 flag definitions.*

The complete list of input parameter keywords is listed below. This list can be generated at any time by calling MSl12 with no parameters,

Keyword	**Definition**	**Default**
par	input parameter file	None
ifile	input L1b file name	None
ofile1	output L2 file #1 name	None
l2prod1	products to be included in ofile #1	nLw chl_oc2
ofile[#]	additional output L2 file names	none
l2prod[#]	products to be included in ofile[#]	none
spixl	start pixel number	1
epixl	end pixel number	the last pixel
dpixl	pixel subsampling interval	1
sline	start line number	1
eline	end line number	the last line
dline	line subsampling interval	1
ctl_pt_incr	control-point pixel increment for lon/lat arrays (0=optimize, >0=user specified)	0
proc_ocean	turn-on/off all ocean-specific processing (0=off, 1=on)	1
proc_land	turn-on/off all land-specific processing (0=off, 1=on)	0
atmocor	turn-on/off atmospheric correction processing (0=off, 1=on)	1
aer_opt	aerosol mode option 1-12: Multi-scattering with fixed model. 12: tropospheric, 99% rh 11: tropospheric, 70% rh 10: tropospheric, 50% rh 9: coastal, 99% rh 8: coastal, 90% rh 7: coastal, 70% rh 6: coastal, 50% rh 5: maritime, 99% rh 4: maritime, 90% rh 3: maritime, 70% rh 2: maritime, 50% rh 1: oceanic, 99% rh 0: Single-scattering white aerosols (CZCS). -1: Multi-scattering with 765/865 Gordon-Wang model selection. -2: Multi-scattering with 670/865 Gordon-Wang model selection. -3: Multi-scattering with 765/865 Gordon-Wang model selection and NIR	-3 for SeaWIFS -1 for OCTS -1 for POLDER -2 for MOS -1 for OSMI

Keyword	Definition	Default
	iterative NIR correction. -4: Multi-scattering with 670/865 Gordon-Wang model selection and iterative NIR correction. 100: Use tau_a_per_band for model selection and aerosol path reflectance calculations.	
tau_a	Input aerosol optical depth at 865 nm (or equivalent). If tau_a > 0 and aer_opt > 0, the input taua and fixed model will be used to derive aerosol reflectance at all pixels, all bands.	-1.0
tau_a_per_band	Input aerosol optical depth at each wavelength. If specified and aer_opt=100, the input aerosol optical thicknesses will be used to select the aerosol models and derive aerosol reflectance at all pixels, all bands.	[0,0,0,0,0,0,0,0]
aer_iter_max	Maximum number of aerosol iterations	10 if NIR corr 2 if glint corr 1 otherwise
glint_opt	correct for residual glint radiance (1: On, 0: Off)	1
foq_opt	perform f/Q correction (1: On, 0: Off)	0
outband_opt	Out-of-band corrections (2: full correction (nLw, Lw, La, Lr), 1: partial correction (La, Lr), 0: Lr only)	0 for MOS, OSMI 2 all others
oxaband_opt	SeaWiFS/OCTS 765nm band Oxygen correction (1: On, 0:Off)	0 for MOS 1 all others
filter_opt	filtering input data option (1: On, 0: Off)	1 for SeaWiFS 1 for OCTS 0 all others
filter_file	data file for input filtering	$MSl12_DATA/*sensor*_filter.dat
demfile	digital elevation map file	$MSl12_DATA/common/digital_elevation_map.hdf
icefile	ice mask file	$MSl12_DATA/common/ice_mask.hdf
sstfile	sea surface temperature file	$MSl12_DATA/common/sst_climatology.hdf
met1	1st meteorological ancillary data file	use climatology
met2	2nd meteorological ancillary data file	None
met3	3rd meteorological ancillary data file	None

Keyword	Definition	Default
ozone1	1st ozone ancillary data file	use climatology
ozone2	2nd ozone ancillary data file	None
ozone3	3rd ozone ancillary data file	None
land	land mask file	$MSl12_DATA/common/landmask.dat
water	shallow water mask file	$MSl12_DATA/common/watermask.dat
calfile	system calibration file	$CAL_HDF_PATH for SeaWiFS $OSMI_CAL_PATH for OSMI
vcal_opt	vicarious calibration option controls whether gains and offsets are taken from the parameter file or sensor defaults: 0=defaults, 1=parameter gain and default offset, 2=default gain and parameter offset, 3=parameter gain and offset	0
offset	calibration offset adjustment	[0.0,0.0,0.0,0.0,0.0,0.0, 0.0,0.0]
gain	calibration gain multiplier	[1.0,1.0,1.0,1.0,1.0,1.0,1.0,1.0]
albedo cloud_thresh	cloud reflectance threshold	0.027
glint glint_thresh	Sun glint threshold	0.005
absaer	Absorbing aerosol threshold on aerosol index. set < -1 to avoid the computation entirely.	0.5
sunzen	sun zenith angle threshold (deg)	75.0
satzen	satellite zenith angle threshold (deg)	60.0
epsmin	minimum epsilon to trigger atmospheric correction failure flag.	0.85
epsmax	maximum epsilon to trigger atmospheric correction failure flag.	1.35
tauamax	maximum 865 aerosol optical depth to trigger hitau flag	0.30
nlwmin	minimum nLw(555) to trigger low Lw flag.	0.15
wsmax	windspeed limit on white-cap correction.	8.0 m/s
maskland	land masking (1: On, 0: Off)	1
maskbath	shallow water masking (1: On, 0: Off)	0
maskcloud	cloud masking (1: On, 0: Off)	1
maskglint	glint masking (1: On, 0: Off)	0
masksunzen	large sun zenith angle mask option (1: On, 0: Off)	0
masksatzen	large satellite zenith angle mask option (1: On, 0: Off)	0
maskhilt	high Lt masking (1: On, 0: Off)	1
maskstlight	stray light masking (1: On, 0: Off)	1
sl_frac	SeaWiFS only: Lt 865 threshold for	0.25

Keyword	Definition	Default
	stray-light correction	
sl_pixl	SeaWiFS only: number of LAC pixels over which stray-light correction is applied. 0=no correction, -1=program selected based on data type (default)	4 for GAC 3 for LAC

Table 3: *MSl12 run-time control parameters.*

Appendix I: Sensor Data Files

MSl12 makes use of external files containing atmospheric correction quantities specific to the individual sensor response functions. For sensors with multiple detectors per band, the average detector response function was used when deriving band-pass-weighted quantities. The sensor files also provide a convenient place to store the band center wavelengths and standard gain coefficients. The wavelengths are used in many SDS and external input file naming conventions, as well as to adjust the aerosol models for non-SeaWiFS wavelengths. The gains are applied to the TOA radiances before atmospheric correction. If gains are also specified through the parameter file, they will be multiplied by the gains in the sensor files to obtain the total gain. The standard sensor files used by MSl12 are listed below.

Appendix Ia: seawifs_table.dat

```
# ------------------------------------------------------------
# SeaWiFS sensor-specific atmospheric correction data
# ------------------------------------------------------------

#
# Wavelengths (um)
#
Lambda(1) = 412
Lambda(2) = 443
Lambda(3) = 490
Lambda(4) = 510
Lambda(5) = 555
Lambda(6) = 670
Lambda(7) = 765
Lambda(8) = 865

#
# Vicarious Calibration Correction Factors
#
# Cal table = SEAWIFS_SENSOR_CAL.TBL-199909
#
Gain(1) = 1.00791
Gain(2) = 0.994429
Gain(3) = 0.963527
Gain(4) = 0.984992
Gain(5) = 0.993924
Gain(6) = 0.958669
Gain(7) = 0.940
Gain(8) = 1.000

Offset(1) = 0.0
Offset(2) = 0.0
Offset(3) = 0.0
Offset(4) = 0.0
Offset(5) = 0.0
Offset(6) = 0.0
Offset(7) = 0.0
```

```
Offset(8) = 0.0

#
# Extraterrestrial Solar Irradiance (mW/cm^2/um/sr)
#
F0(1) = 170.79
F0(2) = 189.45
F0(3) = 193.66
F0(4) = 188.35
F0(5) = 185.33
F0(6) = 153.41
F0(7) = 122.24
F0(8) =  98.82

#
# Rayleigh optical thickness
#
Tau_r(1) = 0.3132
Tau_r(2) = 0.2336
Tau_r(3) = 0.1547
Tau_r(4) = 0.1330
Tau_r(5) = 0.09475
Tau_r(6) = 0.0446
Tau_r(7) = 0.0256
Tau_r(8) = 0.0169

#
# Ozone absorption (/cm)
#
k_oz(1) = 0.00103
k_oz(2) = 0.00400
k_oz(3) = 0.02536
k_oz(4) = 0.04200
k_oz(5) = 0.09338
k_oz(6) = 0.04685
k_oz(7) = 0.00837
k_oz(8) = 0.00485
```

Appendix Ib: mos_table.dat

```
# ------------------------------------------------------------
# MOS sensor-specific atmospheric correction data
# ------------------------------------------------------------

#
# Wavelengths (um)
#
Lambda(1) = 408
Lambda(2) = 443
Lambda(3) = 485
Lambda(4) = 520
Lambda(5) = 570
Lambda(6) = 685
Lambda(7) = 750
Lambda(8) = 870
```

```
#
# Calibration Correction Factors
#
Gain(1) = 0.946831
Gain(2) = 0.897056
Gain(3) = 0.864608
Gain(4) = 0.902115
Gain(5) = 0.909514
Gain(6) = 1.003546
Gain(7) = 1.128976
Gain(8) = 1.000000

Offset(1) = 0.0
Offset(2) = 0.0
Offset(3) = 0.0
Offset(4) = 0.0
Offset(5) = 0.0
Offset(6) = 0.0
Offset(7) = 0.0
Offset(8) = 0.0

#
# Extraterrestrial Solar Irradiance (mW/cm^2/um/sr)
#
F0(1) = 168.77
F0(2) = 189.03
F0(3) = 194.73
F0(4) = 182.36
F0(5) = 184.59
F0(6) = 147.48
F0(7) = 127.26
F0(8) =  96.65

#
# Rayleigh optical thickness
#
Tau_r(1) = 0.3322
Tau_r(2) = 0.2351
Tau_r(3) = 0.1640
Tau_r(4) = 0.1220
Tau_r(5) = 0.0841
Tau_r(6) = 0.0399
Tau_r(7) = 0.0278
Tau_r(8) = 0.0153

#
# Ozone absorption (/cm)
#
k_oz(1) = 0.00076
k_oz(2) = 0.00379
k_oz(3) = 0.02120
k_oz(4) = 0.04930
k_oz(5) = 0.12348
k_oz(6) = 0.03395
k_oz(7) = 0.01021
k_oz(8) = 0.00367
```

Appendix Ic: octs_table.dat

```
# ------------------------------------------------------------
# OCTS sensor-specific atmospheric correction data
# ------------------------------------------------------------

#
# Calibration Correction Factors
#

# NASDA V.4 (Commented-out)
#Gain(1) = 1.14
#Gain(2) = 1.03
#Gain(3) = 0.9394
#Gain(4) = 1.00
#Gain(5) = 1.04
#Gain(6) = 1.00
#Gain(7) = 1.02
#Gain(8) = 0.89

# MOBY-based Calibration
Gain(1) = 1.12287
Gain(2) = 1.01338
Gain(3) = 0.942895
Gain(4) = 0.998615
Gain(5) = 1.02615
Gain(6) = 0.99
Gain(7) = 0.912054
Gain(8) = 0.890000

Offset(1) = 0.0
Offset(2) = 0.0
Offset(3) = 0.0
Offset(4) = 0.0
Offset(5) = 0.0
Offset(6) = 0.0
Offset(7) = 0.0
Offset(8) = 0.0

#
# Wavelengths (um)
#
Lambda(1) = 412
Lambda(2) = 443
Lambda(3) = 490
Lambda(4) = 520
Lambda(5) = 565
Lambda(6) = 670
Lambda(7) = 765
Lambda(8) = 865

#
# Extraterrestrial Solar Irradiance (mW/cm^2/um/sr)
#
```

```
F0(1) = 171.06
F0(2) = 188.48
F0(3) = 194.56
F0(4) = 185.59
F0(5) = 183.33
F0(6) = 152.43
F0(7) = 122.39
F0(8) =  98.48

#
# Rayleigh optical thickness
#
Tau_r(1) = 0.3131
Tau_r(2) = 0.23335
Tau_r(3) = 0.1557
Tau_r(4) = 0.1266
Tau_r(5) = 0.0859
Tau_r(6) = 0.0440
Tau_r(7) = 0.0256
Tau_r(8) = 0.0158

#
# Ozone absorption (/cm)
#
k_oz(1) = 0.00153
k_oz(2) = 0.00436
k_oz(3) = 0.02497
k_oz(4) = 0.04698
k_oz(5) = 0.11117
k_oz(6) = 0.04735
k_oz(7) = 0.00827
k_oz(8) = 0.00373
```

Appendix Id: polder_table.dat

```
# ------------------------------------------------------------
# Polder sensor-specific atmospheric correction data
# ------------------------------------------------------------

#
# Wavelengths (um)
#
Lambda(1) = 443
Lambda(2) = 490
Lambda(3) = 565
Lambda(4) = 670
Lambda(5) = 765
Lambda(6) = 865

#
# Calibration Correction Factors
#
Gain(1) = 1.0
Gain(2) = 1.0
Gain(3) = 1.0
```

```
Gain(4) = 1.0
Gain(5) = 1.0
Gain(6) = 1.0

Offset(1) = 0.0
Offset(2) = 0.0
Offset(3) = 0.0
Offset(4) = 0.0
Offset(5) = 0.0
Offset(6) = 0.0

#
# Extraterrestrial Solar Irradiance (mW/cm^2/um/sr)
#
F0(1) = 189.92
F0(2) = 193.13
F0(3) = 184.66
F0(4) = 152.94
F0(5) = 123.04
F0(6) =  98.60

#
# Rayleigh optical thickness
#
Tau_r(1) = 0.2326
Tau_r(2) = 0.1535
Tau_r(3) = 0.0876
Tau_r(4) = 0.0436
Tau_r(5) = 0.0259
Tau_r(6) = 0.0159

#
# Ozone absorption (/cm)
#
k_oz(1) = 0.00412
k_oz(2) = 0.02564
k_oz(3) = 0.11163
k_oz(4) = 0.04554
k_oz(5) = 0.00846
k_oz(6) = 0.00374
```